

Correlating the Solar Wind and Coronal Holes from Different Viewpoints

WHPI Workshop, September 13-17, 2021

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Impact on Earth of Solar Activity in WHPI Solar Minimum (2018-2020)

Coronal Mass Ejections (CMEs):

Max Dst -65 nT and max ap of 94 nT (linearized Kp of 6+) on May 14, 2019

High-Speed Streams (HSS) of solar wind:

(1) Nov 2018 – Mar 2019, 9-day recurring HSS (CR2211-2214)

(2) Jul-Nov 2019 with 27-day recurring HSS with min and max in CR2219-2224:

Dst -32, -53, -52, -49, -46, -28 nT on Jul 10, Aug 5, Sep 1, Sep 27, Oct 25, Nov 23

ap 48, 56, 56, 56, 56, 27 nT on 191, 217, 244, 270, 298, 327 day#

Kp 5, 5+, 5+, 5+, 5+, 4

We will examine HSS from the sun from 3 different viewpoints: Earth, STEREO-A, and Mars (1.5AU), and trace them back to the coronal holes (CHs) on the sun using a Potential Field Source Surface (PFSS) model of Marc DeRosa and colleagues from the Lockheed Martin Solar and Astrophysics Laboratory (LMSAL) in California.

Radial solar wind velocity from the sun to 5.5au on November 23, 2019 for CR2223 HSS

2019-11-23T14:00

Using ENLIL Model

2019-10-27T07 +27.28 days

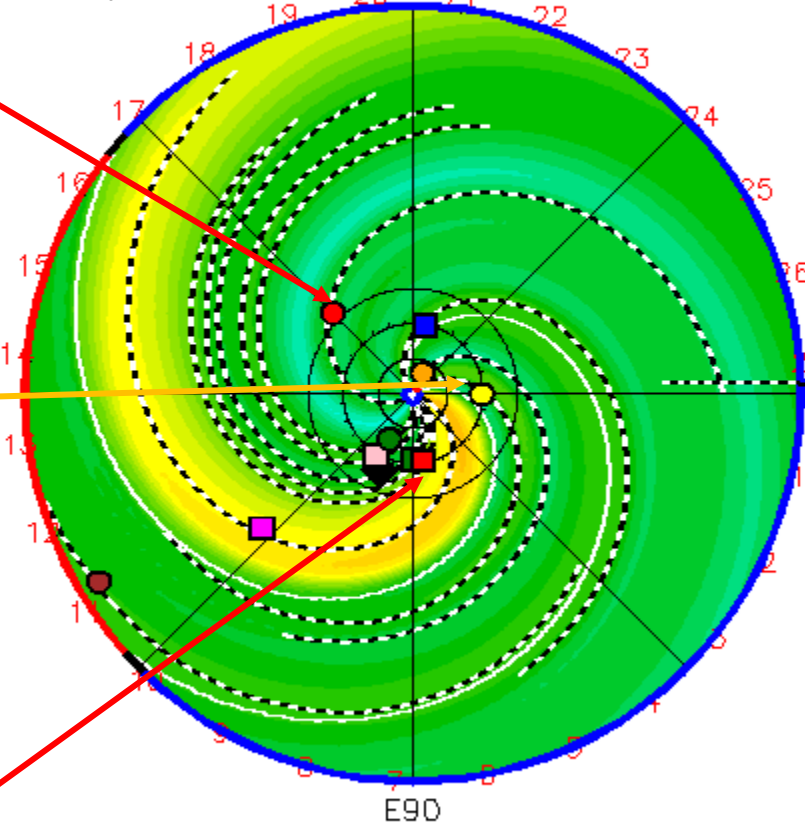
- Earth
- Jupiter
- Mars
- Mercury
- Venus
- Dawn
- ◆ OSIRIS-REx
- ParkerSP
- Spitzer
- Stereo_A
- Stereo_B

Mars

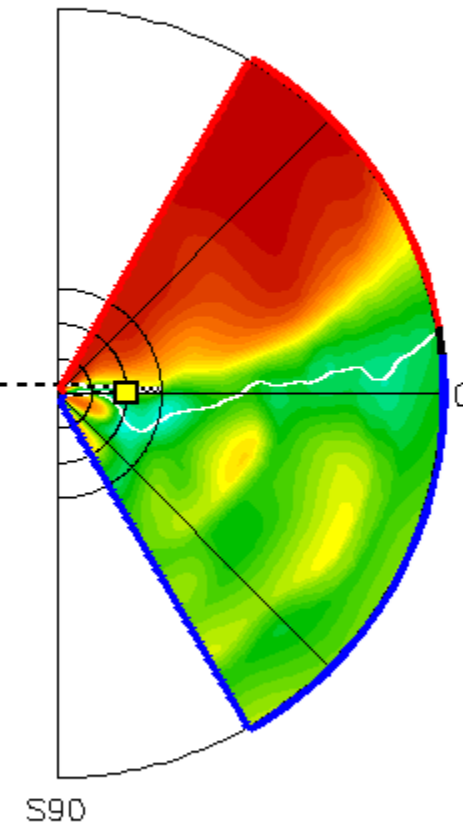
Earth

STEREO-A

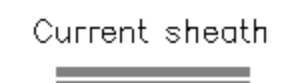
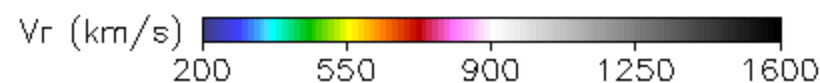
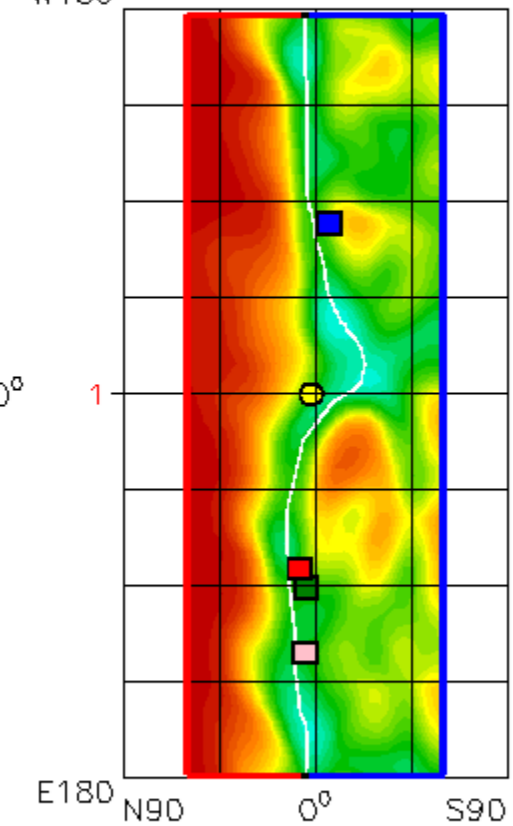
Ecliptic Plane W90 21 LAT = -0.8°



N90 LON = 0°



W180 R = 1.0 AU



McIntosh Style Coronal Hole (SDO/AIA) Synoptic Map

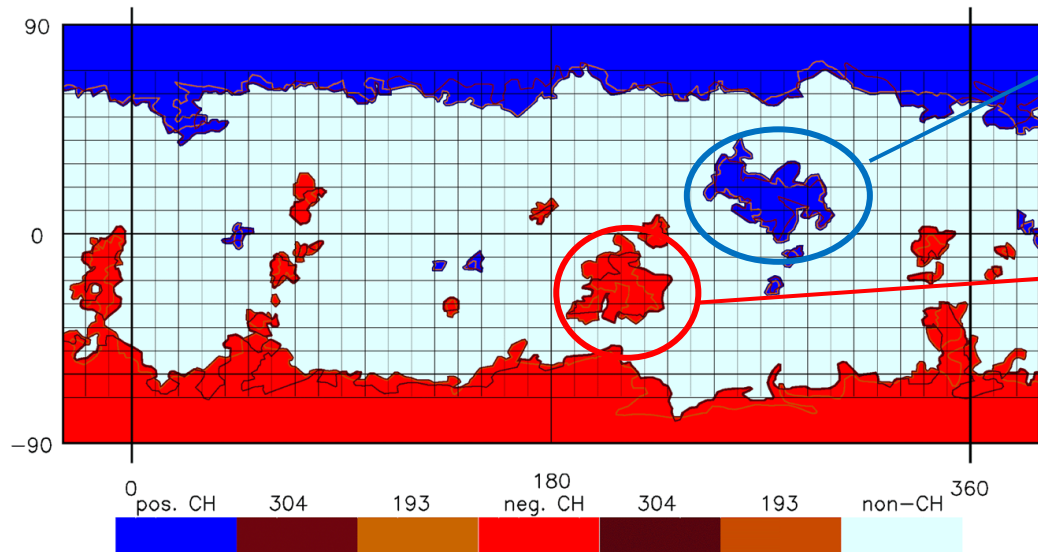
End date (longitude=0):2019-11-12T17:46:11

Start date (longitude=360):2019-10-16T10:34:43

B angle end date 3.170

B angle start date 5.800

CR2223we



Second biggest Northern (N) CH area of positive polarity in WHPI, preferred longitude $\sim 270^\circ$, moves prograde.

Largest Southern (S) CH area of negative polarity in WHPI, Preferred longitude $\sim 200^\circ$, stationary ($\sim 25-29^\circ S$) plus 2 weaker longitudes.

McIntosh Style Coronal Hole (STEREO-A) Synoptic Map

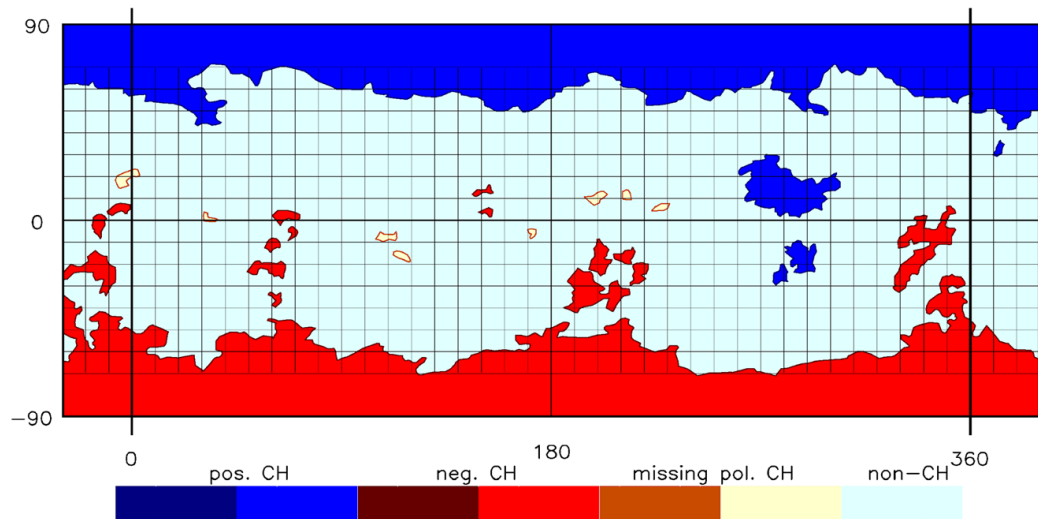
End date (longitude=0):2019-11-06T13:50:47

Start date (longitude=360):2019-10-10T03:33:48

B angle end date 6.800

B angle start date 4.590

CR2223wa



October-November 2019 Coronal Holes that lead to High-Speed Streams (HSS) of Solar Wind Velocity seen at Earth and STEREO-A.

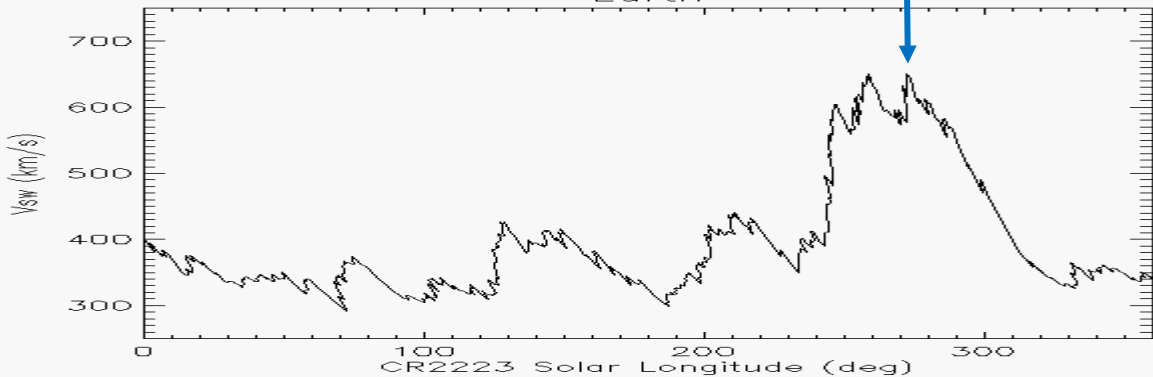
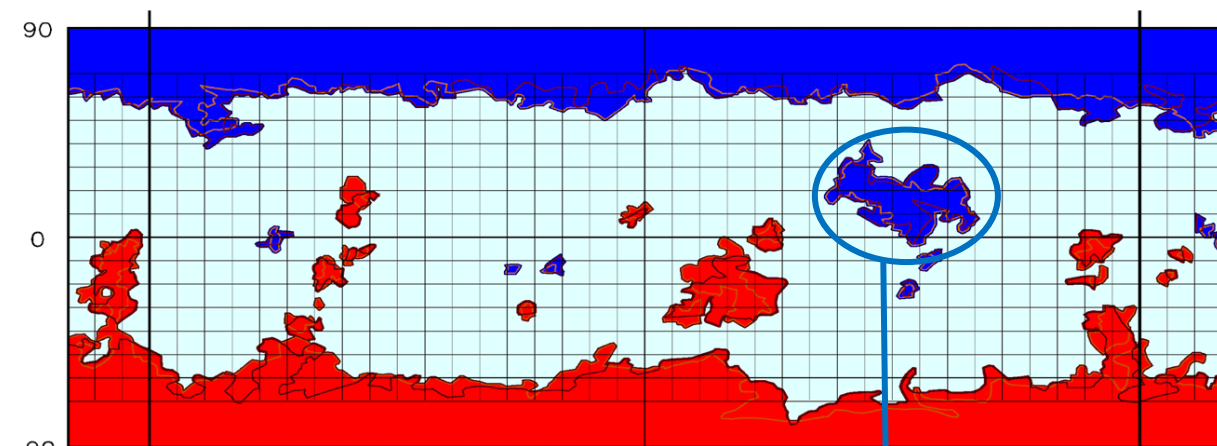
The Largest Solar Wind HSS $\sim 600\text{km/s}$ is in the same longitude sector as the N+ CH when mapped back radially from the Earth and STEREO-A to the Sun assuming constant velocity.

McIntosh Style Coronal Hole (SDO/AIA) Synoptic Map

End date (longitude=0):2019-11-12T17:46:11

B angle end date 3.170

CR2223we

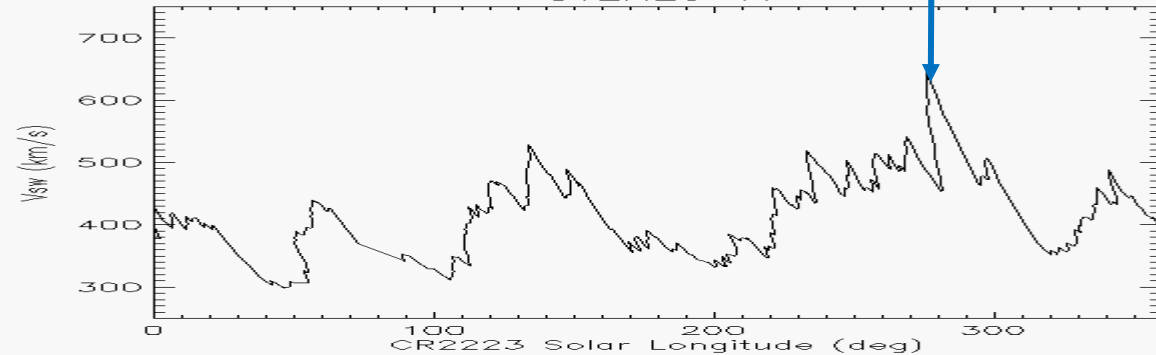
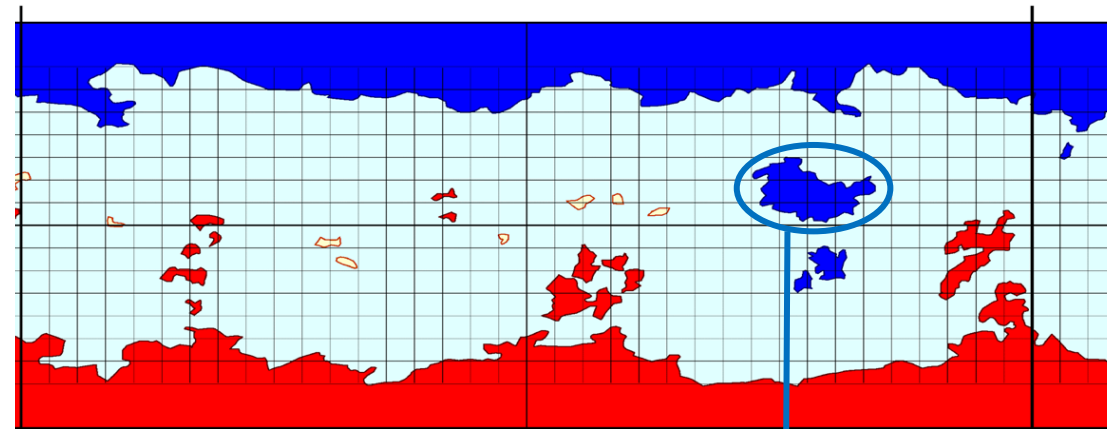


McIntosh Style Coronal Hole (STEREO-A) Synoptic Map

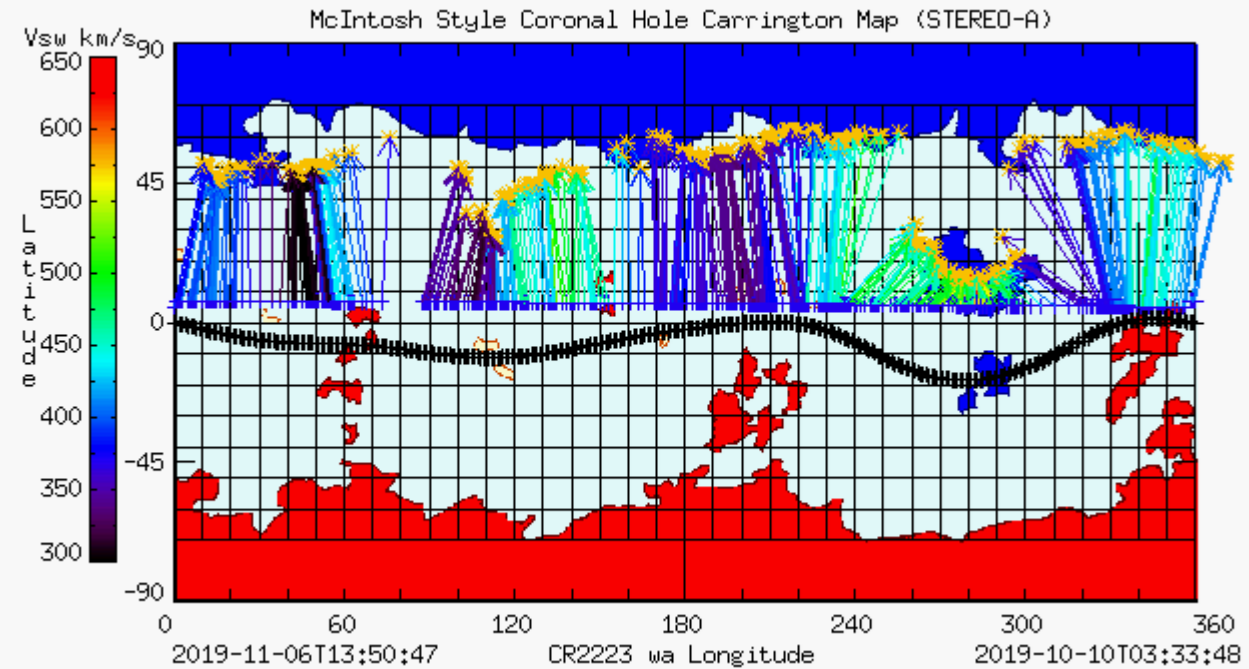
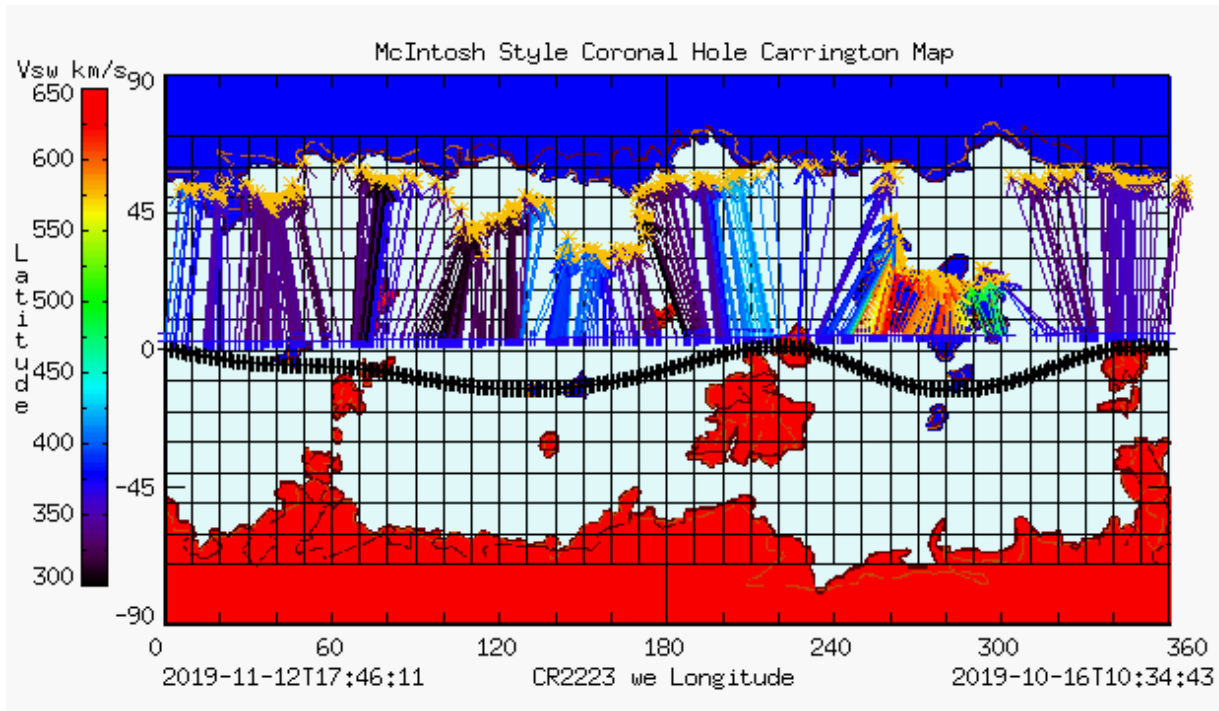
End date (longitude=0):2019-11-06T13:50:47

B angle end date 6.800

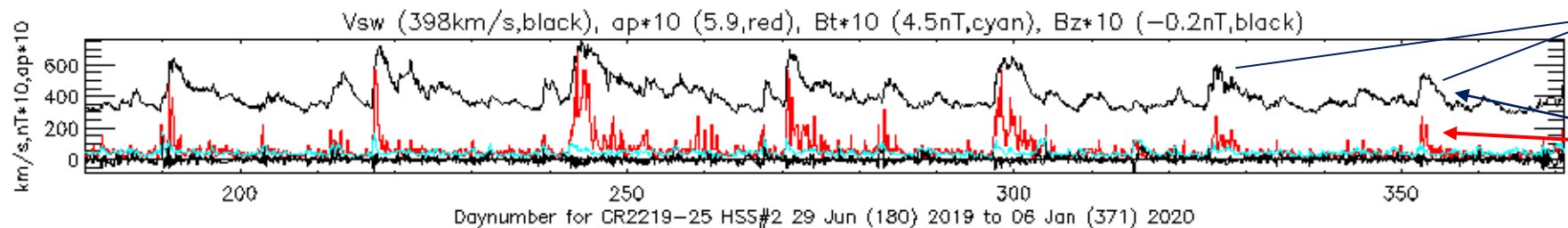
CR2223wa



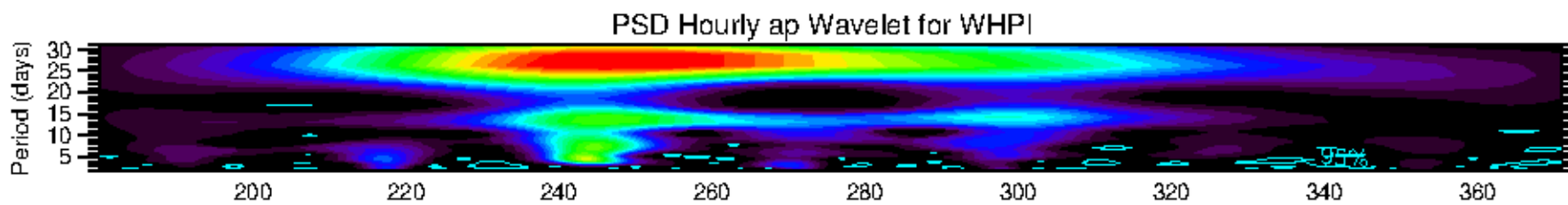
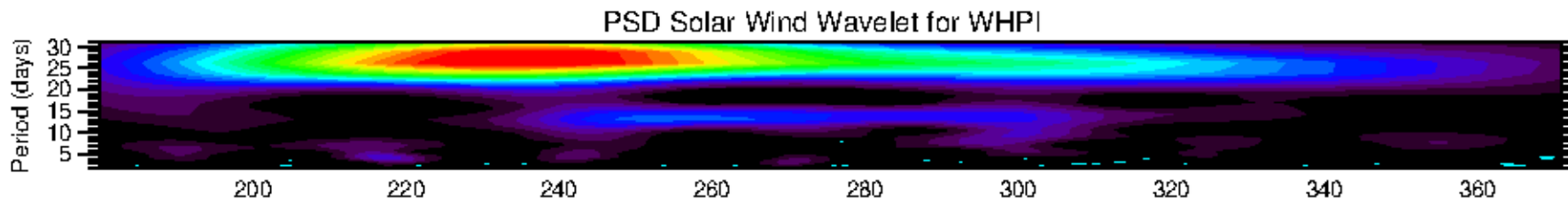
PFSS footpoints (*) from Source Surface (+++) at largest velocity goes to N+CH



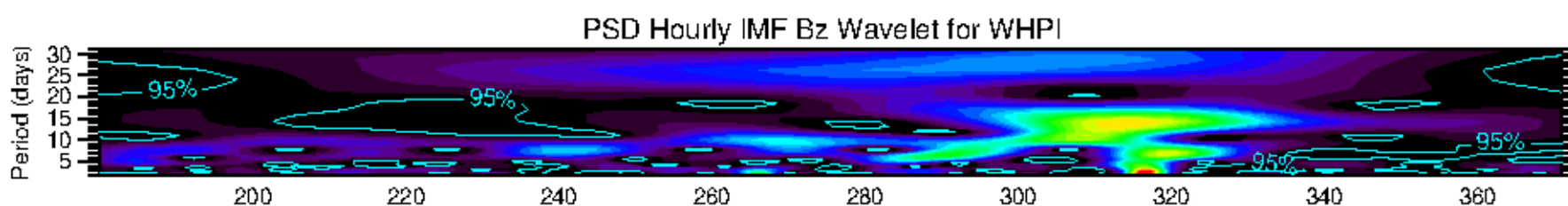
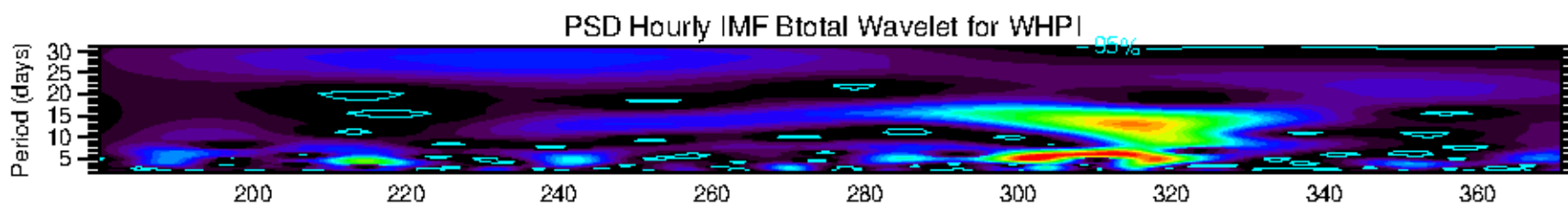
No footpoints (*) at arrow tips with color bar from the solar wind velocity) going to the S- CHs because the source surface (black +++s) is all below the ecliptic plane (blue +++s)



7 CRs 2219-2225
 27-day periodicity in
 Solar Wind and **ap**



13-day periodicity
 in **ap**



June 29, 2019

Jan 6, 2020

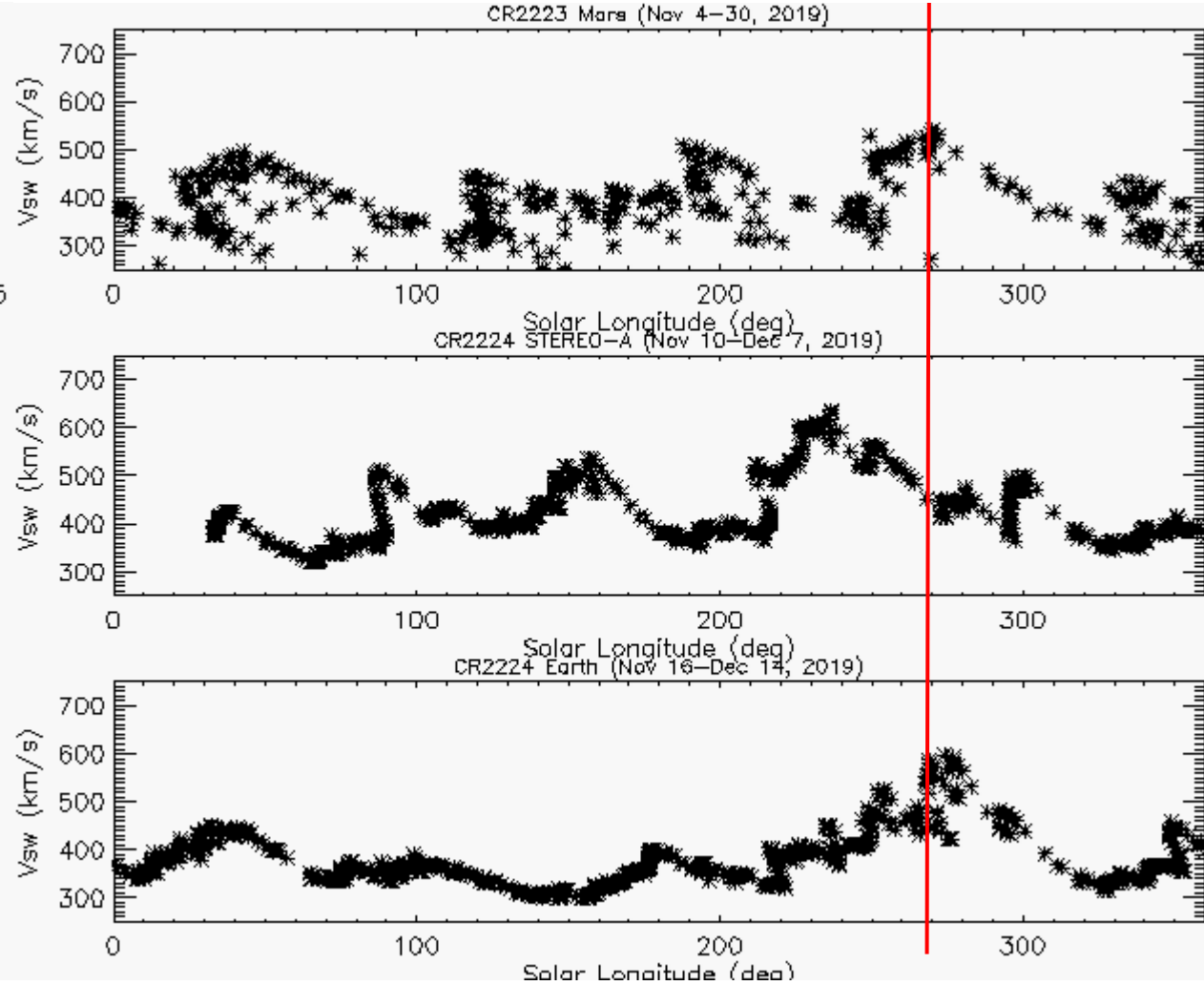
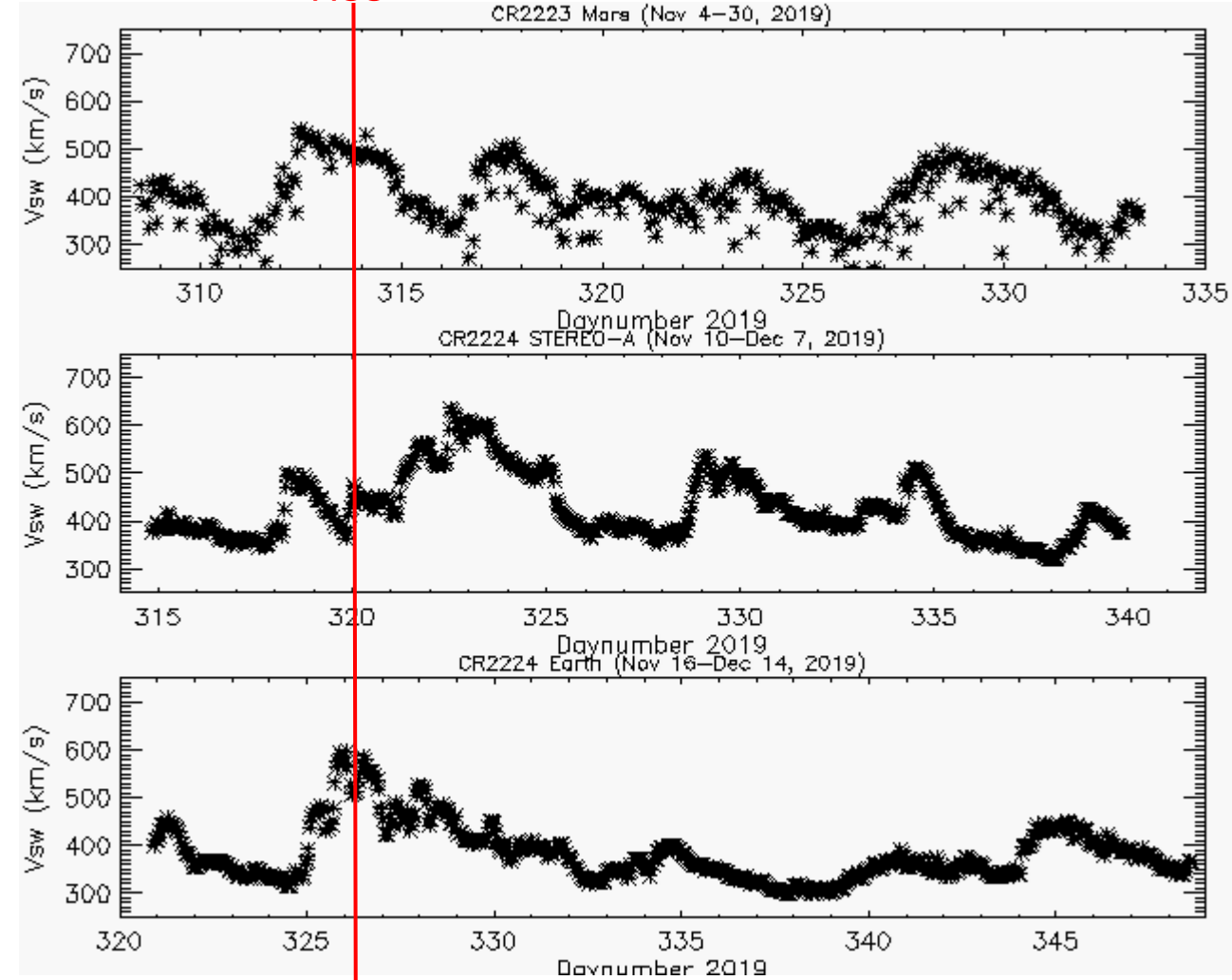
Mars Solar Wind from Maven/SWIA for CR2224(3)

Mars is ~6 days before STEREO-A, which is ~6 days before Earth

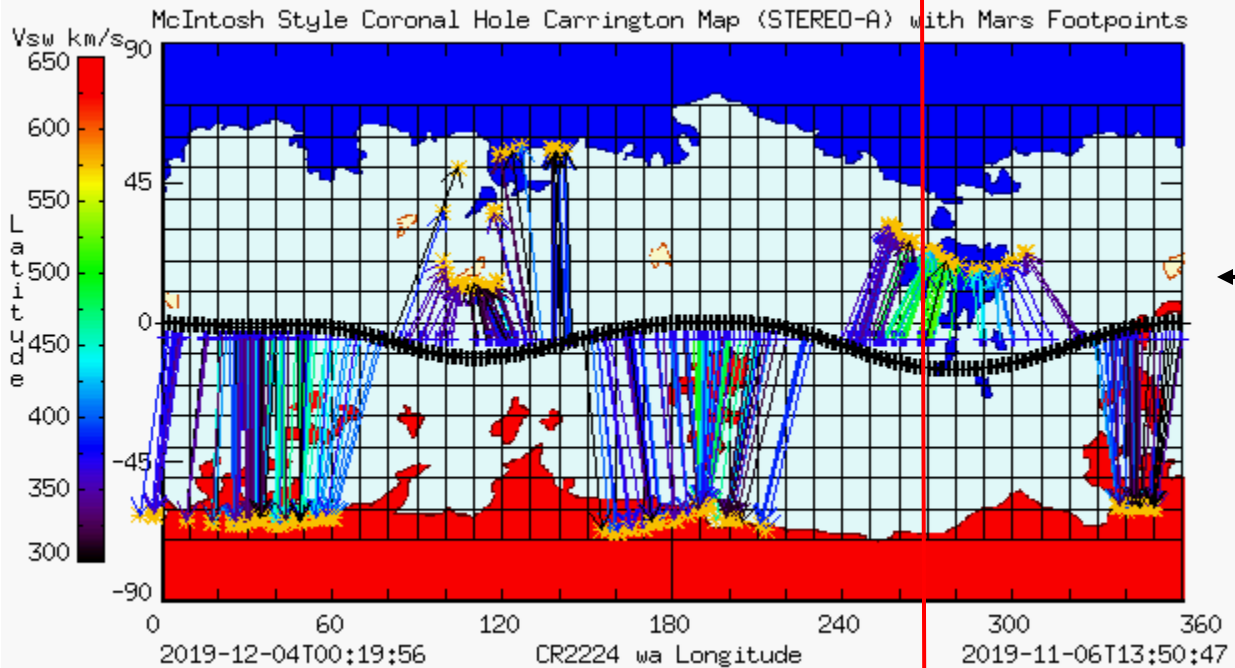
Mapping back to the Solar Longitude

HSS at ~270°

HSS



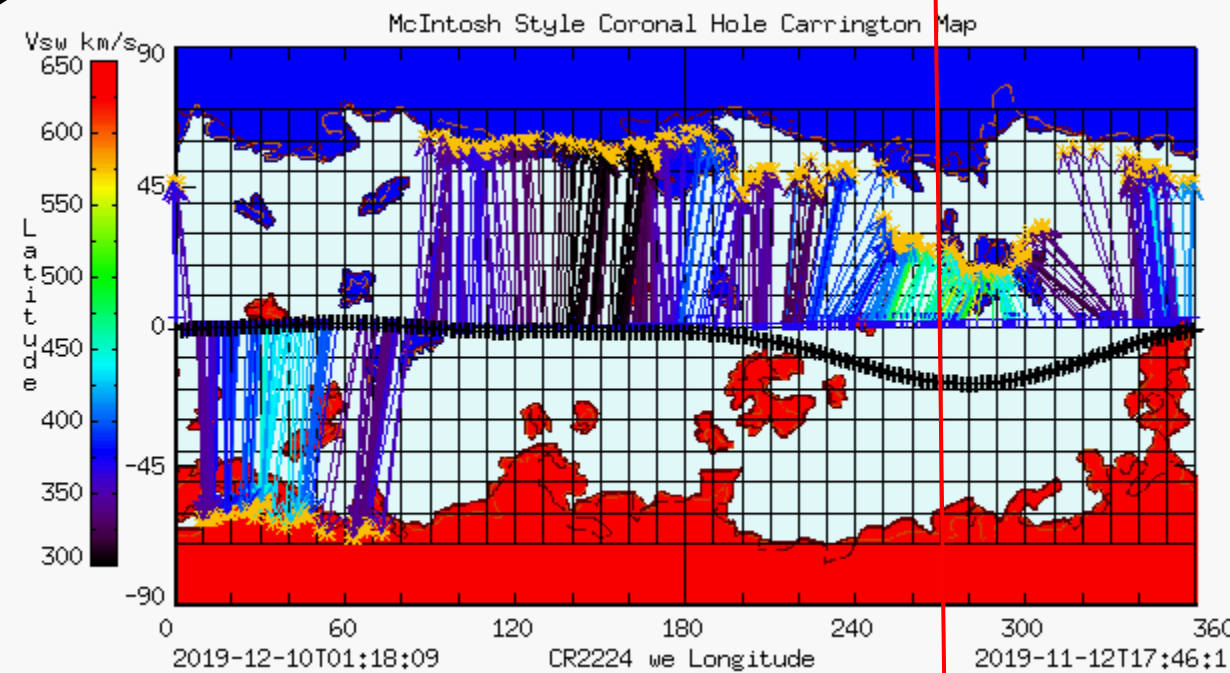
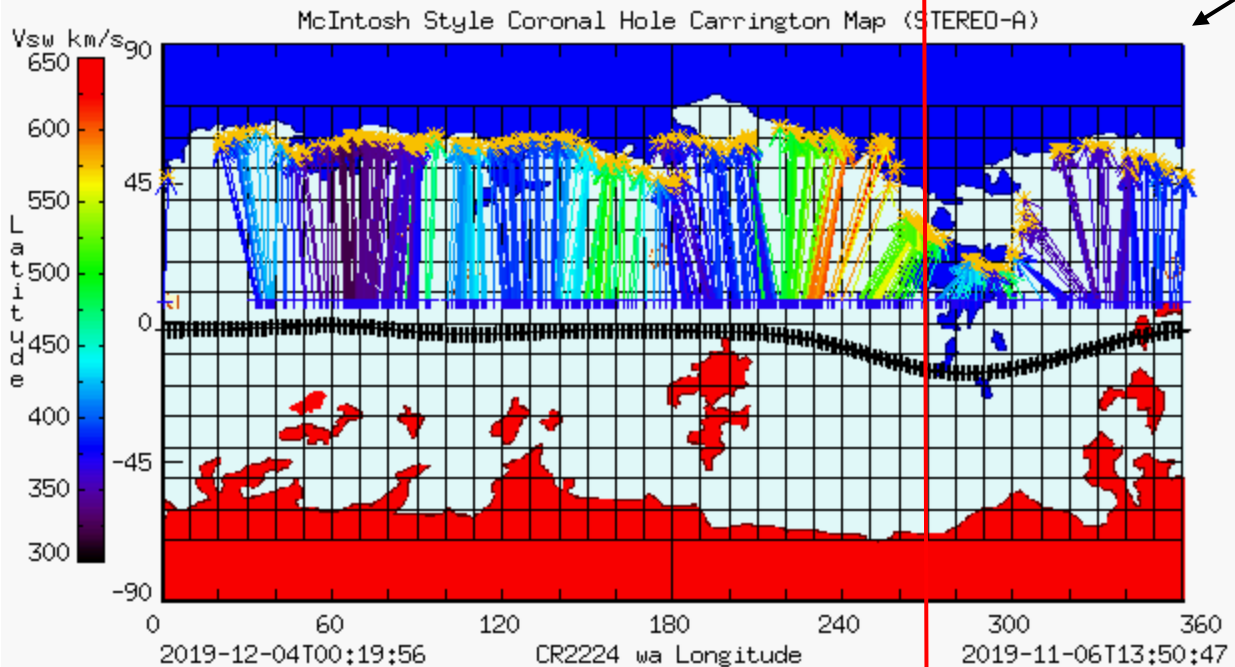
HSS ~270°



CR2224 CH maps with PFSS footpoints (*)
from Source Surface (+++) using back-
mapped solar wind from:
Mars (on STEREO-A CH map)

STEREO-A
Earth

HSS ~270°



McIntosh Style Coronal Hole (SDO/AIA) Synoptic Map

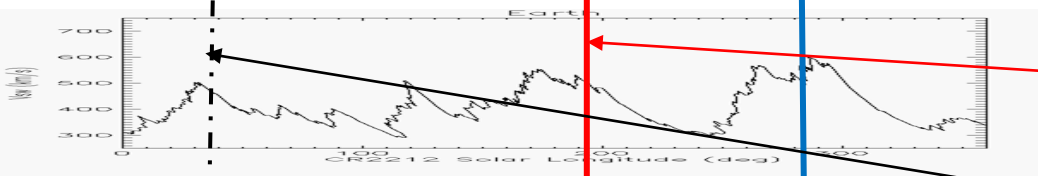
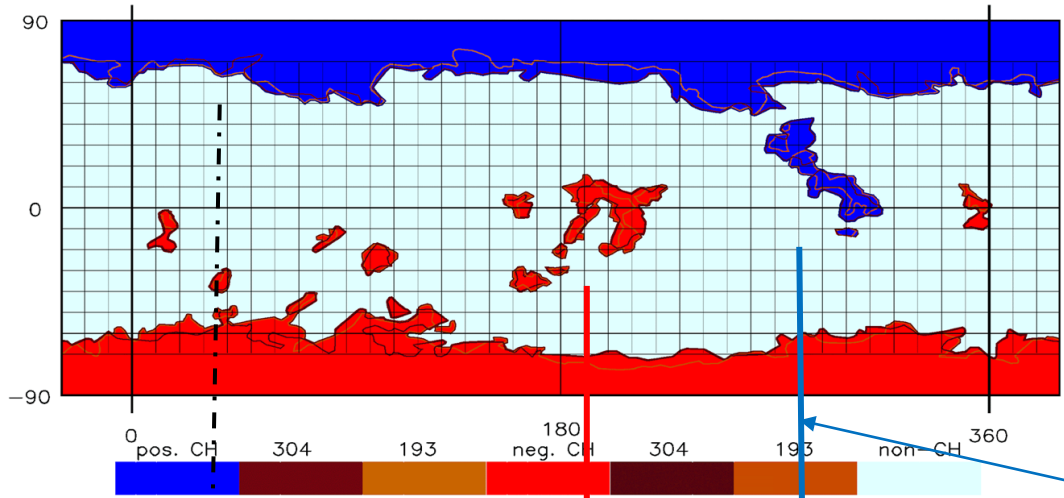
End date (longitude=0):2019-01-16T19:54:55

Start date (longitude=360):2018-12-20T11:53:28

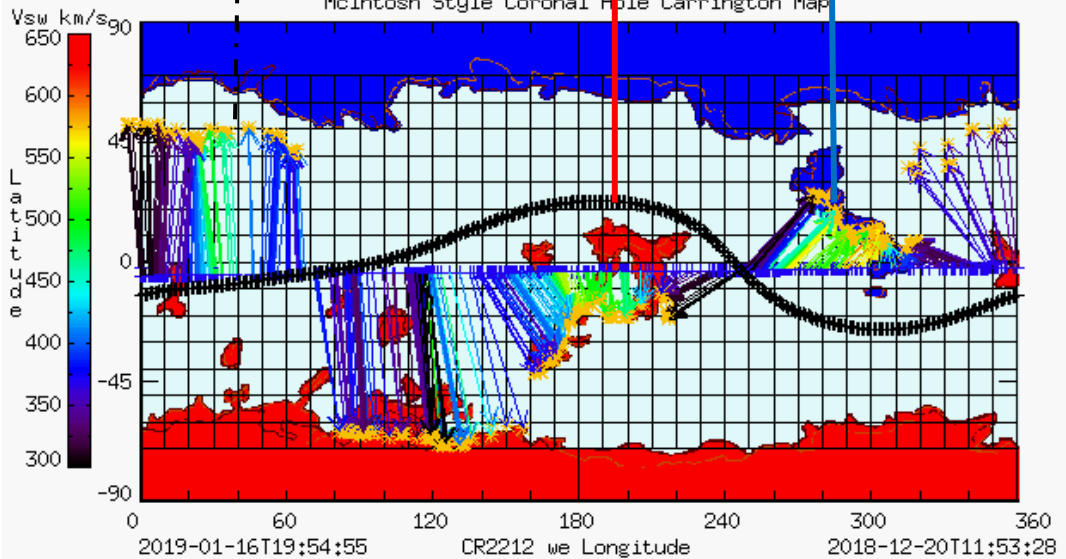
B angle end date -4.69

B angle start date -1.57

CR2212we



McIntosh Style Coronal Hole Carrington Map



McIntosh Style Coronal Hole (STEREO-A) Synoptic Map

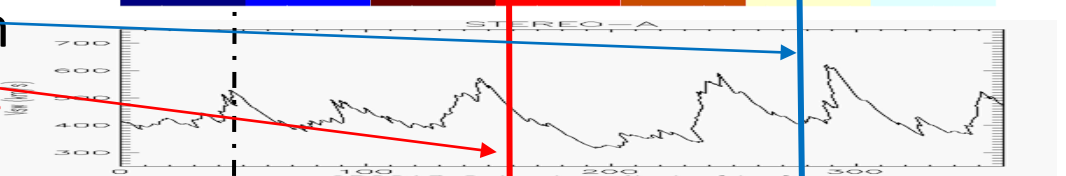
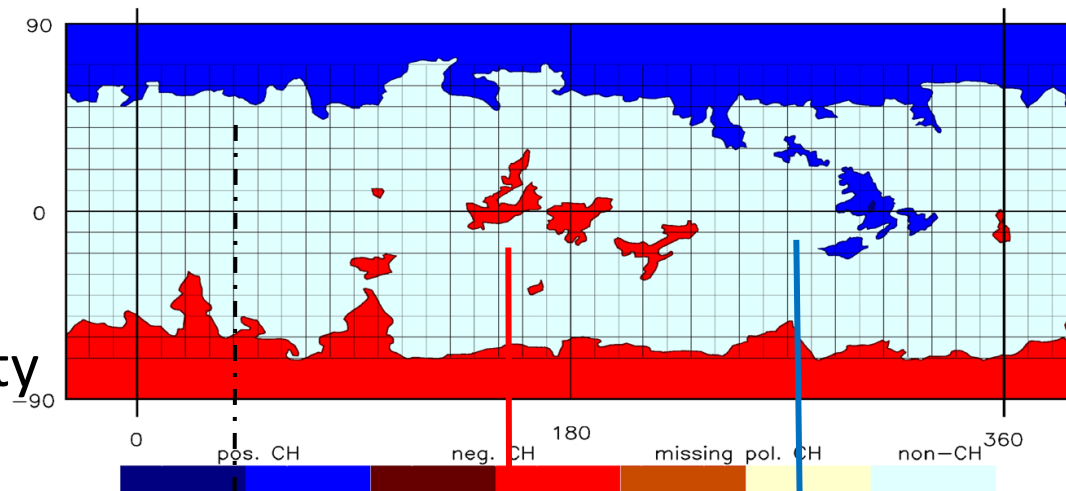
End date (longitude=0):2019-02-05T15:51:41

Start date (longitude=360):2019-01-09T06:02:47

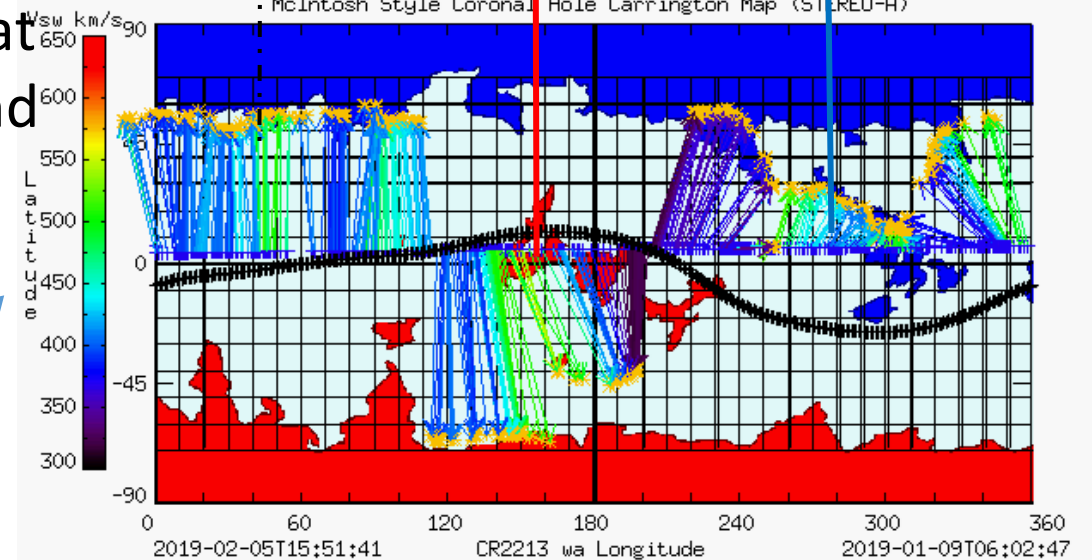
B angle end date 4.520

B angle start date 6.750

CR2213wa

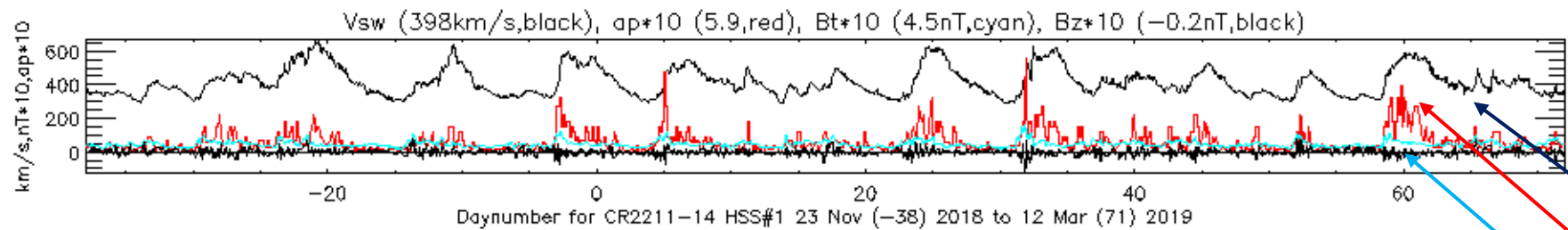


McIntosh Style Coronal Hole Carrington Map (STEREO-A)



9-day periodicity in HSS

Vsw from N+ CH, S- CH, N pole(?) at Earth and ST-A



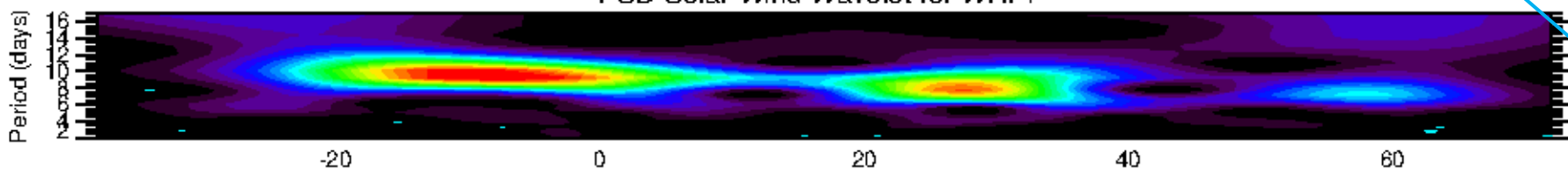
4 CRs 2211-2214

9-day periods in solar wind

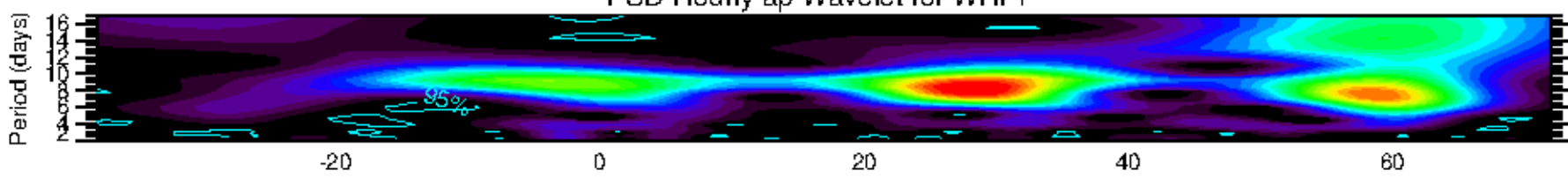
ap (+13-day at end)

IMF |B|

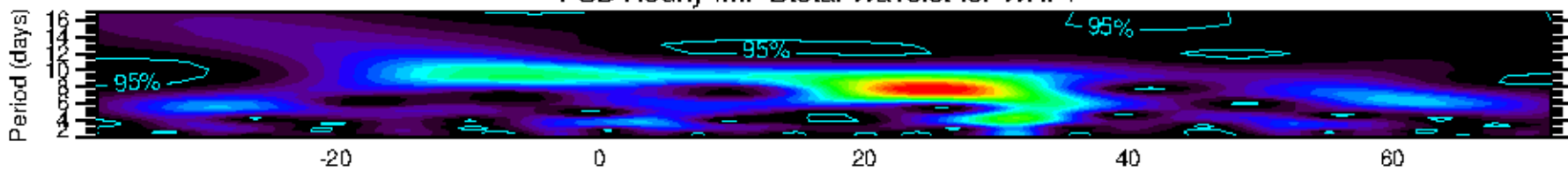
PSD Solar Wind Wavelet for WHP1



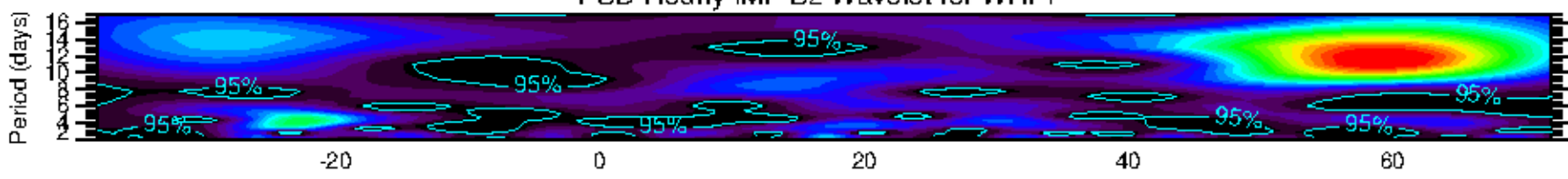
PSD Hourly ap Wavelet for WHP1



PSD Hourly IMF Btotal Wavelet for WHP1



PSD Hourly IMF Bz Wavelet for WHP1



(27-day not shown)

Nov 23, 2018

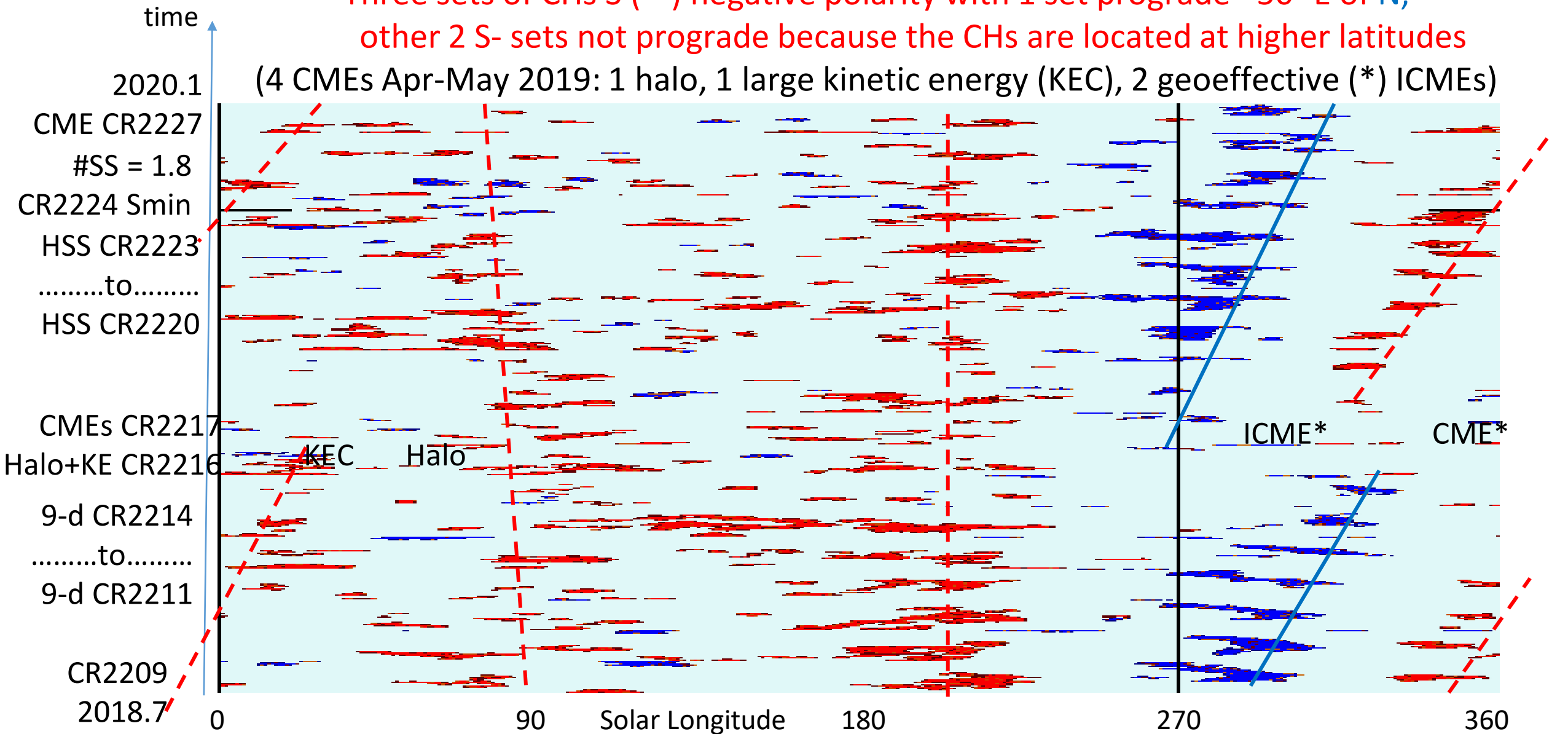
Mar 12, 2019

Solar Minimum WHPI SC 24-25 (2018.7-2020.1), N+ S- CH polarity

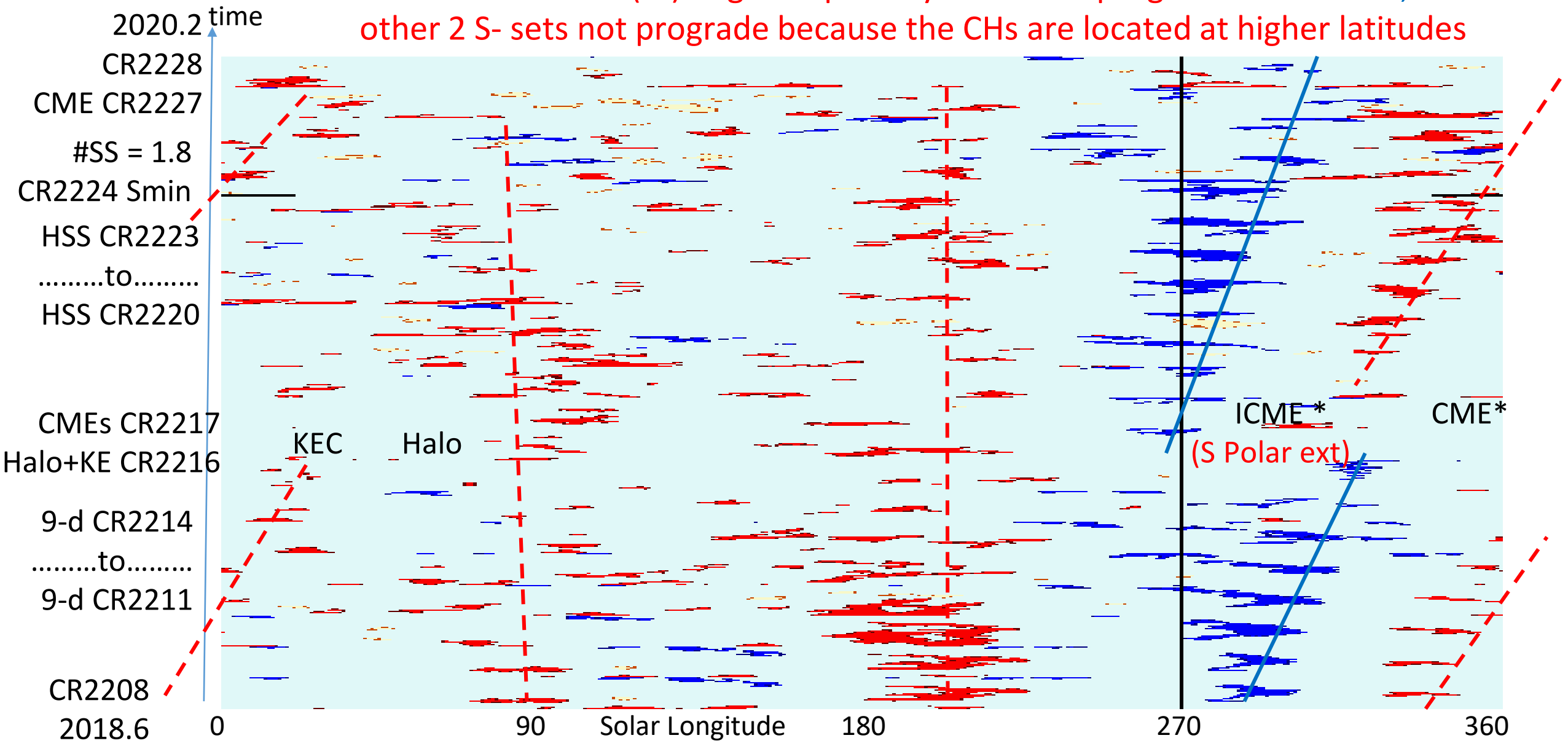
Largest CHs equatorial N positive polarity $\sim 270^\circ$ move $\sim 6^\circ/\text{CR}$ prograde with CME disruption

Three sets of CHs S (- -) negative polarity with 1 set prograde $\sim 50^\circ$ E of N,
other 2 S- sets not prograde because the CHs are located at higher latitudes

(4 CMEs Apr-May 2019: 1 halo, 1 large kinetic energy (KEC), 2 geoeffective (*) ICMEs)



STEREO-A Solar Minimum WHPI SC 24-25 (2018.6-2020.2), N+ S- CH polarity
 Largest CHs equatorial N positive polarity $\sim 270^\circ$ move $\sim 6^\circ/\text{CR}$ prograde with CME disruption
 Three sets of CHs S (- -) negative polarity with 1 set prograde $\sim 50^\circ$ E of N,
 other 2 S- sets not prograde because the CHs are located at higher latitudes



Correlations of Different Perspectives of the Solar Wind to Coronal Holes and High-Speed Streams (HSS)

- 1) STEREO-A is ~6 days Ahead of the Earth, and sees similar CHs and solar wind magnitudes.
- 2) The solar wind at Mars is outside the magneto-sheath of Mars about half the time, and shows similar HSS peaks ~6 days ahead of STEREO-A and ~12 days ahead of Earth views.
- 3) The HSS of solar wind have a strong 27-day component (mostly from the **N+ CHs moving prograde from ~270°**), with 9-day appearing ~CR2211-2214.
- 4) Mapbacks of the constant radial solar wind to a source surface with the Potential Field model PFSS may not always give the correct source surface location or the correct coronal hole source.
- 5) WHPI solar minimum has many low-latitude coronal holes, with 1 set of N positive polarity CHs and 3 sets of S negative polarity CHs. The N and one S set move prograde ~6°/CR since they are equatorial. The other two S CH sets are at higher southern latitudes and are approximately the Carrington rotation rate (relatively constant longitude on our maps).
- 6) CMEs can disrupt the location of the CHs so they reset at their preferred longitudes (~270° for N) and disappear for 1-2 CRs.